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Ground-Testing Techniques for Tethered Systems

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On November 21 and 22, 1988 TDU-34 tow target tests were conducted at the David Taylor Research Center. The purposes of these tests were to determine the launch characteristics of the TDU-34A/A tow target, which had hit the A-6 aircraft during its initial launch. Additional test objectives were the validation of the Tow Target Trajectory Program and an investigation of the ability of the Influence Function Method to predict tow target trajectories.

Nomenclature

ALFXY = indicated angle in yaw, positive outboard, deg
ALFXZ = indicated angle in pitch, positive up, deg
BL = aircraft buttline, positive outboard, in.
C_m = pitching moment coefficient
C_N = normal force coefficient
FS = aircraft X coordinate, positive aft, in.
WL = aircraft Z coordinate, positive down, in.
XREL = X displacement along inertial axis of target's c.g. relative to target's initial c.g. before launch, ft
YREL = Y displacement along inertial axis of target's c.g. relative to target's initial c.g. before launch, ft
ZREL = Z displacement along inertial axis to target's c.g. relative to target's initial c.g. before launch, ft

Introduction

THE TDU-34A (Fig. 1) tow target is used extensively in Navy training operations. A modified target consisting of a 20-in. extension and increased internal systems weight, designated the TDU-34A/A, hit the A-6E aircraft during its initial launch. Since testing was required to reinstate flight clearance for this target on the A-6E aircraft, a wind-tunnel test was designed to match the initial launch conditions that occurred prior to the incident.

Since previous 1/4-scale freestream tests[1] had demonstrated that the TDU-34A and TDU-34A/A targets had identical freestream characteristics, meaning that the 20-in. extension had no effect on the target aerodynamics, only a model of the TDU-34A/A was constructed and tested.

In an effort to improve target stability, two new targets were also designed and tested. One was constructed by removing the first 10 in. of the TDU-34A/A target's tail fins at a 15-deg leading-edge sweep angle. It was designated the TDU-34G. The other one was designed with a totally new H tail, designated the TDU-34H, Fig. 2. Furthermore, a model of the reeling machine with a movable saddle was included in the test to investigate the effects of saddle orientation on launch dynamics, Fig. 2.

Description of the Wind-Tunnel Test

The test was conducted at the David Taylor Research Center (DTRC) transonic 7- × 10-ft wind tunnel. The aircraft, reeling machine, saddle combination, and the three tow targets were modeled at one-sixteenth full scale.

The test consisted of a freestream, grid and trajectory phase for the three different tow targets. Testing was done for the saddle mounted in the nominal position, 3 deg nose down relative to the nominal launch, and with the saddle removed. To simplify the terminology, the TDU-34A/A, TDU-34G, and TDU-34H targets will be referred to subsequently as the 34A, 34G, and 34H respectively.

The Captive Trajectory System (CTS) was modified to constrain the trajectory to a separation acceleration rate of 1.2 ft/s^2, which is the acceleration limitation of the RMK-31 reeling machine.

Freestream Results

The normal force and pitching moment characteristics of the 34A and 34H tow targets are shown in Figs. 3 and 4 (the 34G characteristics are not shown since they were similar to those for the H tail). Also shown in the figures are Interference Distributed Loads (IDL) code predictions of the freetream characteristics for the targets. The IDL code shows excellent agreement with the test data up to an angle of attack of 12 deg and predicts the different trends in C_N and C_m at the higher pitch attitudes for the three targets.

Since the IDL code was also used to predict the influence coefficients[3] for the three targets, which were needed to predict the flowfield at the target launch position, the excellent agreement with the freestream test data was gratifying.

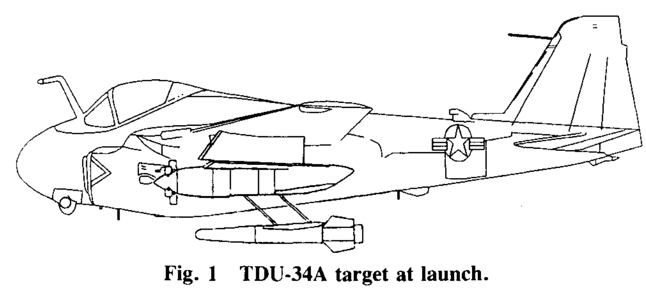

Fig. 1 TDU-34A target at launch.

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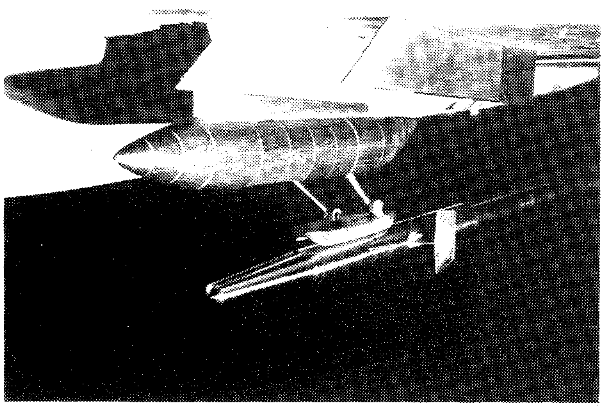

Fig. 2 Wind-tunnel model of TDU-34H and A-6E.

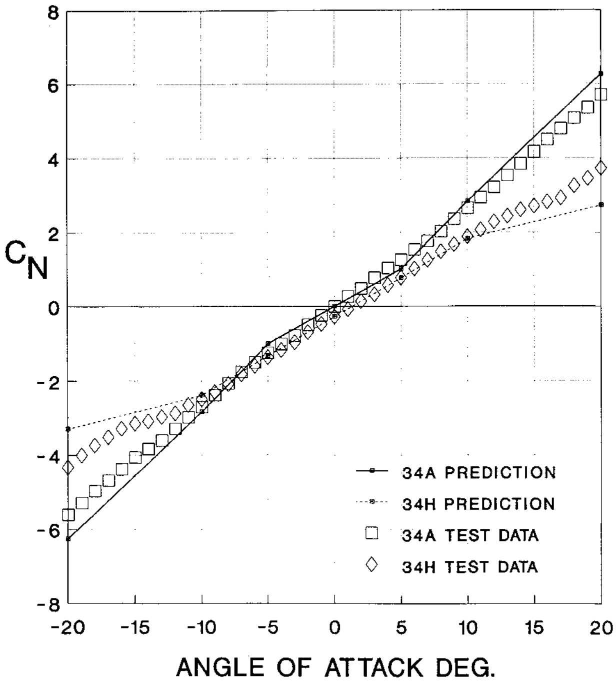

Fig. 3 TDU-34 normal force at M = 0.37.

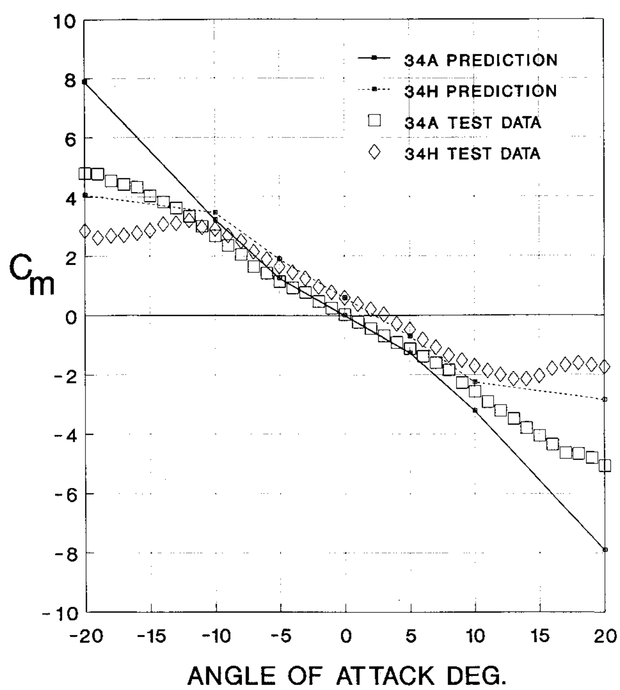

Fig. 4 TDU-34 pitching moment at M = 0.37.

Note that the 34H target exhibits a significant normal force and moment at zero angle of attack. This is attributed to machining effects since this target was made by removing the tail of the 34A model and installing the H tail.

Influence Function Method Flowfield Predictions

The grid traverse data at WL = 25, BL = 95 for the three stores were used, in conjunction with the IDL derived influence coefficients, to predict the flowfield at that traverse, Fig. 5. The close correspondence between the three flowfield predictions indicates their validity, considering that the targets' pitch and yaw attitudes varied by as much as 0.25 deg during their traverse. The Influence Function Method (IFM) tech-

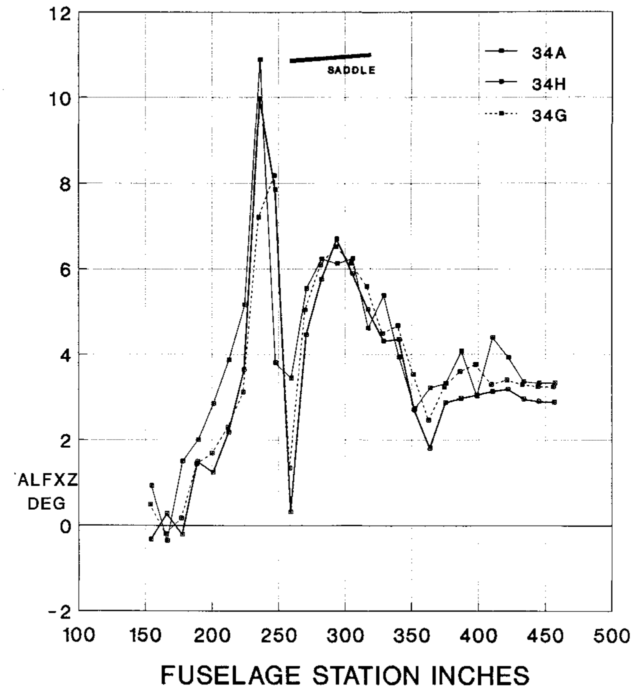

Fig. 5 IFM BL 95 WL 25 ALFXZ prediction.

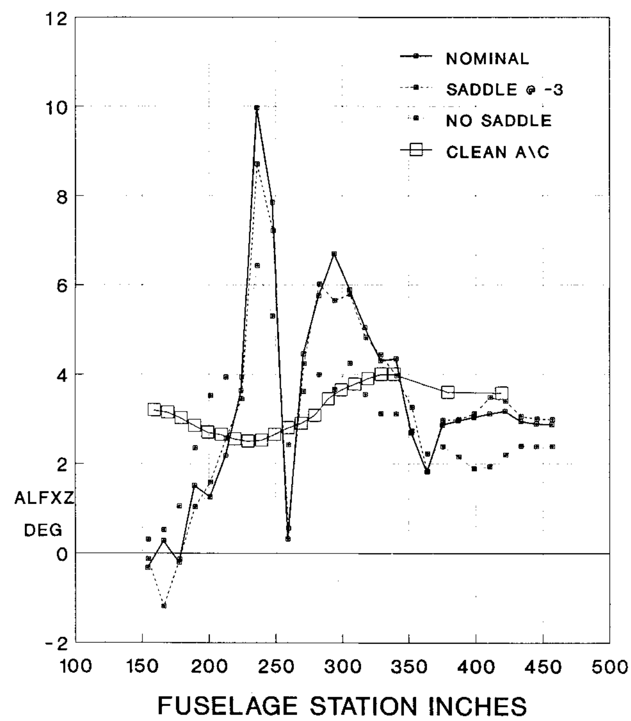

Fig. 6 A-6E saddle flowfield effect.

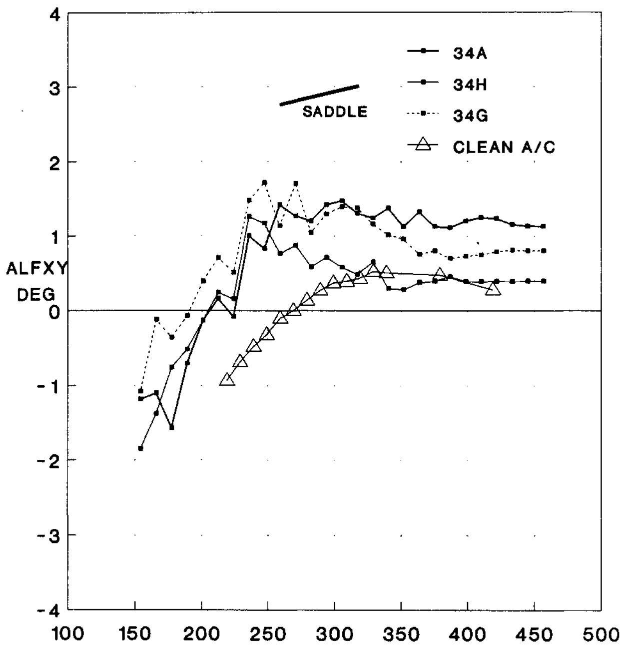

Fig. 7 IFM BL 95 WL 25 ALF*XY* prediction.

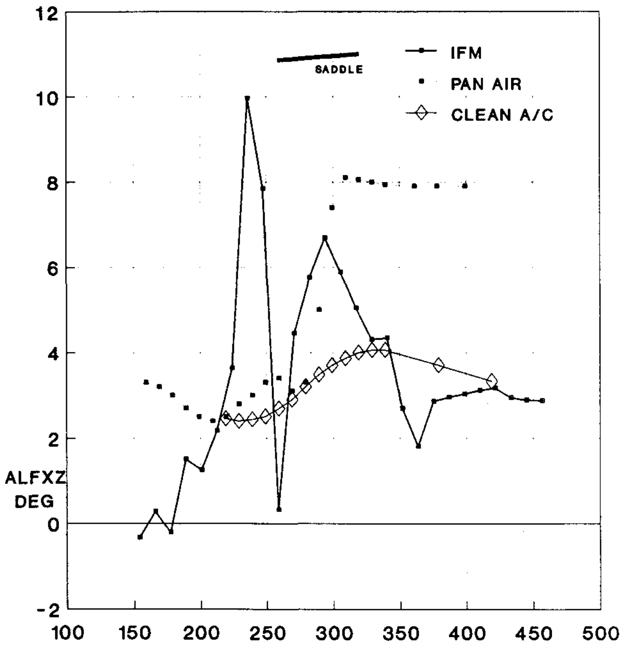

Fig. 8 IFM predicted mutual interference.

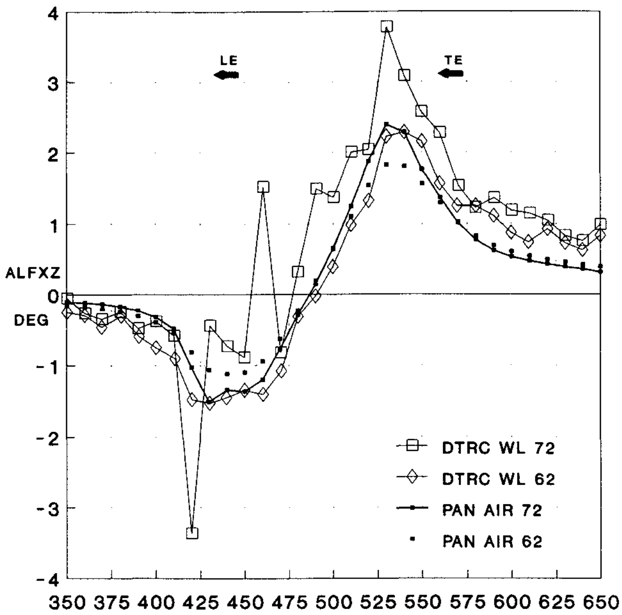

Fig. 9 F-18 PAN AIR ALF*XZ* predictions.

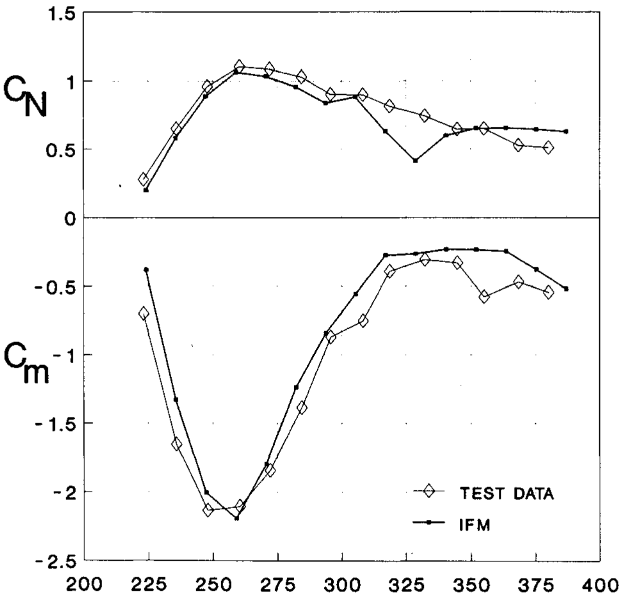

Fig. 10 TDU-34G predictions from TDU-34A.

nique has previously established[3] the ability to predict aircraft flowfields, on the basis of horizontal force and moment grid data, to within 0.5 deg of probe flowfield test data. Note that the flowfield peak near fuselage station 250 is predicted by all three tow targets and occurs some 10 in. forward of the saddle leading edge.

Figure 6 shows the IFM derived flowfield variation at this traverse for the three saddle orientations. Removing the saddle decreases the angularity that the target sees by about 50%, which implies that the reeling machine flowfield has a significant impact on the target's behavior. The clean aircraft flowfield at this traverse location is negligible.

The IFM predicted sidewash is shown in Fig. 7. The saddle orientation has minimal effect on the sidewash at the launch position, with all three predictions differing by <1 deg from the clean aircraft wind-tunnel test data.

Figure 8 compares the IFM predicted flowfield with the PAN AIR flowfield prediction for the A-6E aircraft with the reeling machine and saddle modeled and clean aircraft test data. Both PAN AIR and IFM predict a large increase in ALF*XZ* at FS 270. This can be attributed to the flowfield effects of the saddle. The large disagreement between the PAN AIR flowfield prediction and the three IFM predictions at FS 230–250 can only be attributed to mutual interference effects between the saddle and the target's tails. Somewhat similar behavior was recently observed in the measured probe flowfield data near the F-18 pylon, Fig. 9.

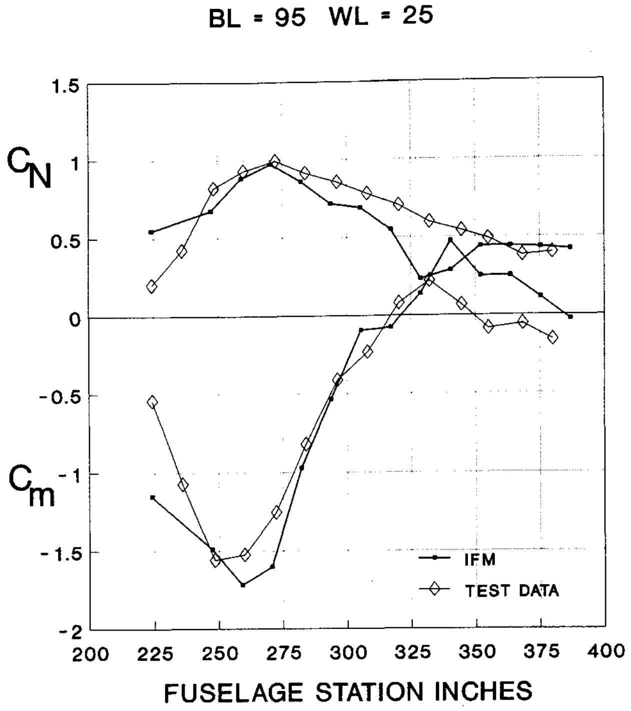

Fig. 11 TDU-34H predictions from TDU-34A.

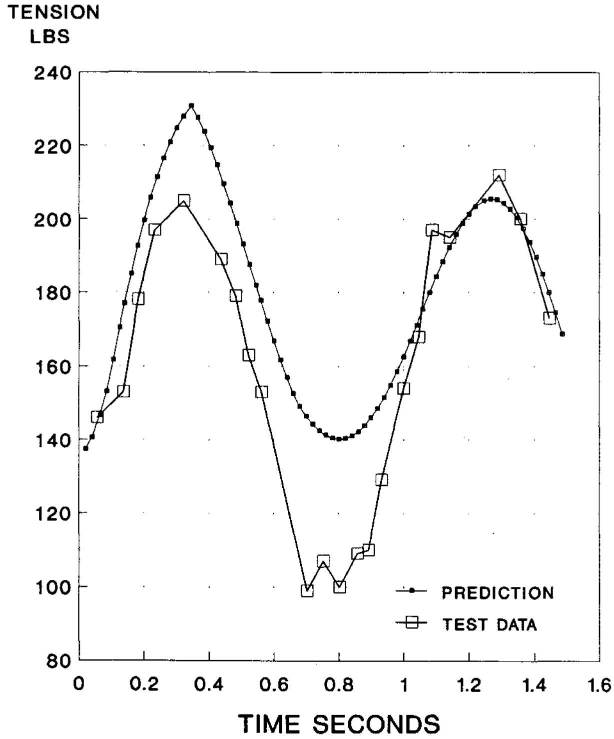

Fig. 12 Cable tension comparison.

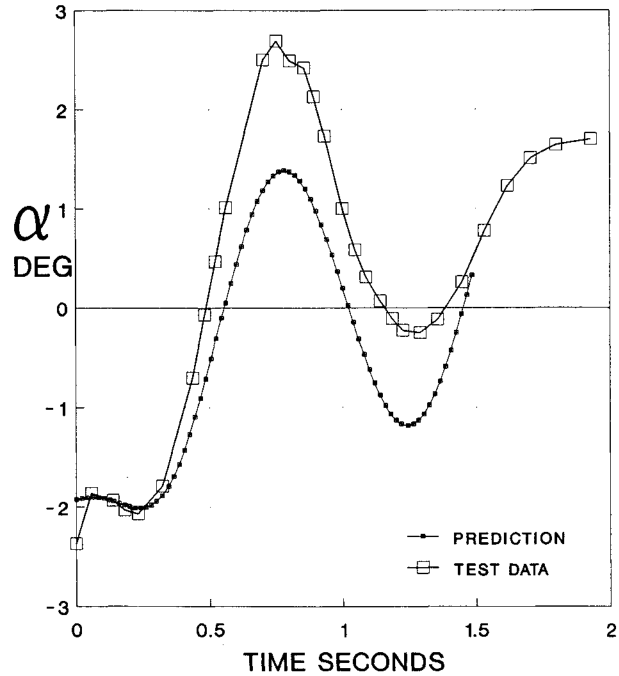

Fig. 13 TDU-34A pitch comparison.

An important measure of the utility of the IFM is its ability to predict store forces and moments based on grid data for another store. As maybe seen in Figs. 10 and 11, 34H and 34G forces and moments, based on 34A grid test data, are in good agreement with the measured grid loads along that traverse, including the region where mutual interference effects predominate. This implies that the grid data collected in this test will be useful for analyzing the launch dynamics of other possible tow target configurations.

Trajectory Predictions

34A grid data at WL = 25, 15 and BL = 85, 95 in conjunction with the carriage loads and freestream aerodynamics were combined in the Tow Target Trajectory Program (3TP)[4] to predict the target's behavior. The trajectory program was constrained in the same manner as the wind-tunnel test, namely, the acceleration along the cable could not exceed 1.2 ft/s^2.

The tow target models had a balance relatively insensitive in roll. Since the roll was not locked out during the test, and since some targets exhibited unreasonable rolling behavior (1800 deg/s), all pitch and yaw attitude comparisons are in terms of store tunnel settings. Fortunately, the cable tension had a roll stabilizing effect on the trajectories, and only the 34G trajectories are suspect.

Figure 12 compares the tension predicted by the 3TP with the tension measured during the test for the 34A target launched at -3 deg nose down relative to nominal, which was the flight-test condition for which the target hit the aircraft. Since the cable tension is a function of the target's aerodynamics, which are a direct function of the pitch attitude, the disagreement in tension after 0.3 s can be attributed to the discrepancy in target pitch attitude, as seen in Fig. 13. The differences between the test and theory pitch attitudes was attributed to two factors. The target grid data, taken at 10-in. vertical increments, were not spaced closely enough nor extended as far below the launch position as they should have been. Since tow targets separate far more slowly from aircraft than stores and, therefore, are more influenced by the aircraft flowfield, the grid data for tow target testing should be at least twice as dense as for conventional store trajectory tests. Furthermore, the wind-tunnel testing increment was determined by the relative target displacement. This accounted for the large 0.15 s) time increment that occurred at a critical point in the trajectory. In future tests, time, rather than displacement, should be used as the testing interval.

Despite the aforementioned problems, which can be attributed to the fact that tow target trajectory testing is in its infancy, the pitch attitude is in reasonably good agreement with the test data. The displacement is also in good agreement with the test data, Fig. 14.

Since it was determined[1] that the TDU-34A/A target pitched up in excess of 10 deg during the first pitch oscillation before it hit the A-6E aircraft, the behavior seen in Fig. 13 indicates that the incident during flight tests was an anomaly and that the target should be safe to fly.

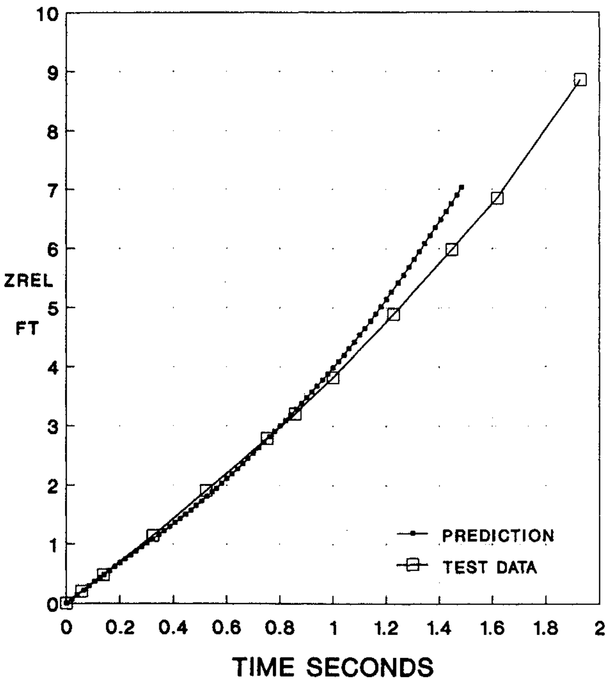

Fig. 14 TDU-34A displacement comparison.

Conclusions

Analysis of the TDU-34/A-6E wind-tunnel test has demonstrated that the 34A tow target has safe separation characteristics for nominal launch conditions from the A-6E aircraft. Based on this analysis, flight clearance for this aircraft/target combination was restored, and recently completed flight tests have validated[5] the wind-tunnel results.

The H-tail configuration (designated as the TDU-34H) exhibits safe launch characteristics. After the TDU-34A/A flight tests are concluded, intentions are to launch this target from the A-6E aircraft.

Removing the saddle seemed to considerably reduce the flowfield that the target would see at launch. Flight tests for this configuration are also planned.

Future tow target tests should consist of more dense vertical grids and have the roll capability locked out. The tests should be conducted with time, rather than displacement, as the testing interval.

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